Method of Test for
DETERMINING THE MINIMUM CEMENT CONTENT FOR INCORPORATION INTO SOILS, SOIL-AGGREGATE OR AGGREGATE MIXTURES FOR STABILIZATION OR TREATMENT
DOTD Designation: TR 432-02

INTRODUCTION

Methods A, B, and C are designed to determine the minimum percentage of cement to be incorporated into soils or soil-aggregate mixtures which have met all other specification requirements for materials to be stabilized or treated. Method D is designed to determine the durability of materials which have met stabilization requirements by Methods A, B, or C.

Materials which do not meet design criteria for strength and durability are not acceptable for use.

There are certain materials, such as sand clay gravel and sand-shell for which the percentage of portland cement is predetermined by specification. This specified cement percentage does not apply to Type II or IP. When Type II or IP cement is used the percent cement must be determined by Method B or C as applicable. For other materials or when portland-pozzolan cement is used, the stabilized test specimen must meet the values in the following chart.

The following chart is applicable unless otherwise specified. The cement factor at other design compressive strengths may be determined using Methods B or C.

MATERIAL	DESIGN COMPRESSIVE STRENGTH
Cement Treated Base Course	150 psi +
Cement Stabilized or Treated Soil, Soil-Aggregate and Recycled Materials	2100 kPa (300 psi) +
Cement Stabilized Sand Clay Gravel	3450 kPa (500 psi) +
Cement Stabilized Sand-Shell	4150 kPa (600 psi) +

These methods of test are to be used only for soils which meet specification requirements.

Methods B and C are the basis for the development of historical strength data for the soils and soil-aggregates listing in Method A – Table 1.

TABLE OF METHODS

1. **Method A** – This method consists of historical data for the minimum required percent cement for these types of soils. Method B or C, as applicable, may be used in lieu of Method A.

   This method is to be used only for naturally occurring soils or soil-aggregates as identified in Table 1, containing 39% or less siliceous gravel or shell using Types I or IB cement. This method is to be used only for soils that have not been previously disturbed in their original geologic location.

   This method is not to be used for any soils where contamination is suspected, such as near a sugar cane field or haul road, an oil field, chemical plant, waste area, etc., nor for any soils which have a history of not stabilizing with cement, or for previously stabilized or treated soils.
2. **Method B** – This method is to be used for soils with less than 5% aggregate.

   This method must be used for soils which have been disturbed from their original geologic location, for soils for which there is no historical data for stabilization, or for which contamination is suspected.

This method is to be used for In-Place Stabilized Base Course when materials contain less than 5% aggregate.

This method is to be used for spoil materials, materials from areas which have previously exhibited poor stabilization results, or blended soils containing less than 5% aggregate.

3. **Method C** – This method is to be used for soil-aggregates with 5% or more aggregate.

This method is to be used when the aggregate content of a naturally occurring soil is 40% or greater by dry mass retained on the 4.75 mm (No. 4) sieve or when the material contains other than siliceous gravel or shell.

This method is to be used for In-Place Stabilized Base Course when materials contain 5% or greater aggregate.

This method is to be used for spoil materials, materials from areas which have previously exhibited poor stabilization results, or blended soils containing less than 5% aggregate.

4. **Method D** – This method of test is to be used when:
   - the soil may be contaminated with sugar, industrial or agricultural chemicals, oil or sulfates,
   - the soil has a high chloride content,
   - the soil has a pH less than 4 or greater than 9, which may be an indicator of contamination.

Method D is not to be used to determine a minimum percent cement for a material which will not stabilize when tested by another method.

REFERENCE DOCUMENTS

1. DOTD TR 403 - Determination of Moisture Content
2. DOTD TR 411M - Dry Preparation of Disturbed Samples for Test
3. DOTD TR 415M - Field Moisture-Density Relationships
4. DOTD TR 418M – Moisture-Density Relationships
5. DOTD TR 423 - Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
6. ASTM D 1633 - Test Method for Compressive Strength of Molded Soil Cement Cylinders
7. AASHTO M 92 - Wire Cloth Sieves for Testing Purposes
8. AASHTO T 135 - Wetting and Drying Test of Compacted Soil Cement Mixtures

DEFINITIONS

For the purpose of this test procedure, the following definitions will apply.

1. **Aggregate:** a crushed or uncrushed material, retained on a 4.75 mm (No. 4) sieve, allowed for incorporation into the soil fraction. However, when testing soils, material retained on the 2.00 mm (No. 10) sieve shall be considered to be aggregate. Previously stabilized or treated materials or other materials retained on the 2.00 mm (No. 10) sieve, including materials containing asphaltic particles or particles of other surfacing, shall be considered as aggregate.
2. **Additive:** an approved lime or other approved additive incorporated dry into the soil or soil-aggregate mixture. When approved liquid additives or slurries are to be incorporated, the testing method will be determined by the Materials Engineer Administrator.
3. **Moisture Content:**
   a. **Optimum moisture content:** optimum moisture of material, without additive.
   b. **Design moisture content:** optimum moisture content of soil curve without additive, plus 0.5% or 1%, depending on soil classification. This is the total moisture content that will be in the final soil cement mixture.

c. **Slake water:** design moisture content minus 5%. This moisture content is used to slake the material without additive.
d. **Net water:** the difference between slake water and design moisture content (5%).
e. **Evaporation:** moisture lost during mixing and molding.

4. **Naturally Occurring Soil or Soil-Aggregates:** in-situ materials which have neither been disturbed nor exposed to the weather, except by normal construction operations for a current project. Materials from spoil banks, old roadways, relic borrow pits, topsoil, etc. are not naturally occurring soil or soil-aggregates.
5. **Soil-aggregate:** a mixture of soil and aggregate.
6. **Stabilization:** the result of adding cement to soil or soil-aggregates to increase the stability, durability, and strength of the soil or soil-aggregate to a specific design requirement.
7. **Treatment:** the result of adding cement to soil or soil-aggregates to increase the stability and strength of the soil or soil-aggregate to a specific design requirement. The strength requirement may be lower than that for stabilization.
8. **Recycled In-Place Materials:** soil or soil-aggregate mixtures which are naturally occurring, containing asphaltic materials, hydraulic cement, lime, or other stabilizers or surfacing, excluding portland cement concrete, which exist in-place and are to be reprocessed.

DOTD Designation: TR 432-02

Method A – Naturally Occurring Soils or Soil-Aggregate

I. Scope

This method is designed to determine the minimum percentage of cement for incorporation into naturally occurring soils or soil-aggregates as identified in Table 1, containing 39% or less siliceous gravel or shell using Types I or IB cement. This method is to be used only for soils that have not been previously disturbed in their original geologic location.

II. Apparatus

A. **Worksheet** – Soils/Soil-Aggregate, DOTD Form No. 03-22-0723, completed except for cement factor (Figure A-1).

B. **Plant Report** – Base Course Design for Central Mix Plant Materials Mixtures, DOTD Form No. 03-22-0752, contractor's submittal (Figure A-2).

III. Sample

No sample required. Must have results of DOTD TR 423 for soil to be used.

IV. Procedure

A. Use the soil type and A-Group classification determined from DOTD TR 423 to enter the left vertical column of Table 1.

B. Locate the parish location on the top row of Table 1.

C. Read the minimum cement factor by volume at the intersection of the row and column.

Note B-1: *The cement percents shown in Table 1, are approximate values and may not be accurate for a specific soil. The engineer is cautioned to consider soil characteristics, borderline classifications, geologic parameters, chemical components, etc. before deciding to use Method A. Method B can be used for all soils at the option of the engineer. Method B shall be performed whenever there is any question of the applicability or accuracy of Method A.*

Note A-1: *If the specification item requires that the minimum cement factor be reported by mass, perform Steps D and E in order to convert the percent by volume to percent by mass. If the specification item requires that the minimum cement factor be reported by volume, go directly to Step V.*

D. Determine the moisture-density relationships of the material in accordance with DOTD TR 415M – Method A or DOTD TR 418M – Method A.

E. Determine the percent of cement by mass by using the Additive Conversion Chart in DOTD TR 418M – Method B.

V. Report

Report the minimum cement factor by volume or by mass as applicable to the specification item.

VI. Normal Test Reporting Time

Normal test reporting time is a maximum of 21 days, including the completion of all prerequisite testing.

PARISH	SANDY LOAM A-2-4, A-4, A-2-6, A-6	SANDY CLAY LOAM A-2-4, A-4, A-2-6, A-6	SANDY CLAY A-2-4, A-4, A-2-6, A-6	LT. SANDY CLAY A-4, A-6	LOAM A-4, A-6	CLAY LOAM A-4, A-6	SILTY LOAM < 61% SILT A-4, A-6	SILTY CLAY LOAM < 61% SILT A-4, A-6	SILTY CLAY <61% SILT A-4, A-6	LT. SILTY CLAY A-4, A-6
ACADIA	10	10	11	11	9	9	12	12	12	11
ALLEN	9	9	10	11	10	9	10	10	10	10
ASCENSION	10	10	11	11	9	9	12	12	12	11
ASSUMPTION	10	10	11	11	9	9	12	12	12	11
AVOYELLES	9	9	10	11	10	9	10	10	10	10
BEUREGARD	9	9	10	11	10	9	10	10	10	10
BIENVILLE	9	9	9	9	9	9	9	9	10	9
BOSSIER	9	9	9	9	9	9	9	9	10	9
CADDO	9	9	9	9	9	9	9	9	10	9
CALCASIEU	9	9	10	10	9	9	10	11	11	10
CALDWELL	9	9	10	10	9	9	11	11	11	10
CAMERON	9	9	10	10	9	9	10	11	11	10
CATAHOULA	9	9	10	10	9	9	11	11	11	10
CLAIBORNE	9	9	9	9	9	9	9	9	10	9
CONCORDIA	9	9	10	10	9	9	11	11	11	10
DESOTO	9	9	9	9	9	9	9	9	10	9
E. BATON ROUGE	10	9	10	10	11	10	11	11	11	10
E. CARROLL	9	9	11	10	9	9	11	11	11	10
E. FELICIANA	10	9	10	10	11	10	11	11	11	10
EVANGELINE	9	9	10	10	9	9	10	11	11	10
FRANKLIN	9	9	10	10	9	9	11	11	11	10
GRANT	9	9	10	11	10	9	10	10	10	10
IBERIA	10	10	11	11	9	9	12	12	12	11
IBERVILLE	10	10	11	11	9	9	12	12	12	11
JACKSON	9	9	11	10	9	9	11	11	11	10
JEFFERSON	10	10	10	10	9	9	11	11	12	11
JEFF DAVIS	9	9	10	10	9	9	10	11	11	10
LAFAYETTE	10	10	11	11	9	9	12	12	12	11
LAFOURCHE	10	10	10	10	9	9	11	11	12	11
LASALLE	9	9	10	10	9	9	11	11	11	10
LINCOLN	9	9	9	9	9	9	9	9	10	9
LIVINGSTON	10	9	10	10	11	10	11	11	11	10
MADISON	9	9	11	10	9	9	11	11	11	10
MOREHOUSE	9	9	11	10	9	9	11	11	11	10
NATCHITOCHES	9	9	10	11	10	9	10	10	10	10
ORLEANS	10	10	10	10	9	9	11	11	12	11
OUACHIA	9	9	11	10	9	9	11	11	11	10
PLAQUEMINES	10	10	10	10	9	9	11	11	12	11
POINTE COUPEE	10	10	11	11	9	9	12	12	12	11
RAPIDES	9	9	10	11	10	9	10	10	10	10
RED RIVER	9	9	9	9	9	9	9	9	10	9
RICHLAND	9	9	11	10	9	9	11	11	11	10
SABINE	9	9	10	11	10	9	10	10	10	10
ST. BERNARD	10	10	10	10	9	9	11	11	12	11
ST. CHARLES	10	10	10	10	9	9	11	11	12	11
ST. HELENA	10	9	10	10	11	10	11	11	11	10
ST. JAMES	10	10	10	10	9	9	11	11	12	11
ST. JOHN	10	10	10	10	9	9	11	11	12	11
ST. LANDRY	10	10	11	11	9	9	12	12	12	11
ST. MARTIN	10	10	11	11	9	9	12	12	12	11
ST. MARY	10	10	11	11	9	9	12	12	12	11
ST. TAMMANY	10	9	10	10	11	10	11	11	11	10
TANGIPAHOA	10	9	10	10	11	10	11	11	11	10
TENSAS	9	9	10	10	9	9	11	11	11	10
TERREBONNE	10	10	10	10	9	9	11	11	12	11
UNION	9	9	9	9	9	9	9	9	10	9
VERMILION	10	10	11	11	9	9	12	12	12	11
VERNON	9	9	10	11	10	9	10	10	10	10
WASHINGTON	10	9	10	10	11	10	11	11	11	10
WEBSTER	9	9	9	9	9	9	9	9	10	9
W. BATON ROUGE	10	10	11	11	9	9	12	12	12	11
W. CARROLL	9	9	11	10	9	9	11	11	11	10
W. FELICIAN	10	9	10	10	11	10	11	11	11	10
WINN	9	9	10	11	10	9	10	10	10	10

NOTE: This chart does not apply to naturally occurring soils with over 79% sand or over 60% silt. Silt contents are based on the unadjusted percentage of silt determined in accordance with DOTD TR 407.

AGGREGATE ADJUSTMENT: The following adjustments may be made according to the occurrence of naturally occurring aggregate found in the above soils.

Ret. on 4.75mm (No.4) (% BY Mass)	Cement Reduction (% BY VOLUME)
0 - 14	0
15 - 39	1

TABLE 1 - CEMENT DETERMINATION BY SOIL CLASSIFICATION AND PARISH LOCATION

MATT MENU SELECTION - 14

Louisiana Department of Transportation and Development
SOILS/SOIL-AGGREGATE

DOTD 03-22-0723
Rev. 10/99

Metric / English M (M or E - Located on MATT Menu)

Project No.	4501-11-0002	Material Code	S21	Lab. No.	22-123456
Date Sampled	03-29-99	Submitted By	0071	Quantity	1000
Purp. Code	7	Pit No.		Spec Code	
Date Tested	04-06-99	Ident.	BS-2	Parish No.	013
From Station	+	To Station	+	Location	
Hole No.		Depth, m (ft)		Log Distance, km (mi)	
Item No.	301(01)	Sampled by:	T.H.		

Remarks 1

Hydrometer Analysis (DOTD TR 407)			Graduate No.	Dry Mass of Sample (W), g (1 = 50.0, 2 = 100.0)			
Time	(T) Elapsed Time	Temp°C (0.5° increments)	(h) Hydro Reading (0.5 increments)	(C) Correction (0.5 increments)	Corrected Reading $H = h - C$	% Finer $P = \frac{H}{W} * 100$	Effect. Grain Size $D = K\sqrt{\frac{L}{T}}$
	60 Minutes	25.5	17.0	3.0			
	120 Minutes	22.5	14.0	3.0			

RETAINED ON 2.00 mm (10)
(TR 418 - Method H)

Mass Cup + Soil, g	
Cup No.	
Mass Cup, g	
Mass Soil, g	

RETAINED ON 425 μm (40)
(TR 407 & 418 - Method H)

Mass Cup + Soil, g	11.6
Cup No.	2A
Mass Cup, g	11.1
Mass Soil, g	0.5

RETAINED ON 75 μm (200)
(TR 407 & 418 - Method H)

Mass Cup + Soil, g	30.6
Cup No	2B
Mass Cup, g	10.6
Mass Soil, g	20.0

Size	Mass Retained (Wx) Gram	%
Total Mass, g		
25.0 mm (1)		
19.0 mm (3/4)		
12.5 mm (1/2)		
4.75 mm (4)		
2.00 mm (10)		
425 μm (40)	0.5	1.0
75 μm (200)	20.0	40.0
% Silt		
% Clay & Colloids		24.0
Pass 4.75 mm (#4)		
Pass 2.00 mm (#10)		

(DOTD TR 407)

% Ret. 25.0 mm (1)	
% Ret. 19.0 mm (3/4)	
% Ret. 12.5 mm (1/2)	
% Ret. 4.75 mm (4)	
% Ret. 2.00 mm (10)	
% Ret. 425 μm (40)	1
% Ret. 75 μm (200)	40
% Silt	35
% Clay & Colloids	24
% Pass 2.00 mm (#10)	100
% Pass 425 μm (40)	99
% Pass 75 μm (200)	59
% Sand (Tot. Material)	41
% Unadjusted Silt	35
% Unadjusted Sand	41
% Unadjusted Clay	24

LIQUID LIMIT

No. Blows	20
Mass Cup + Wet Soil, g	25.5
Mass Cup + Dry Soil, g	20.4
Mass Water, g	5.1
Factor	0.9733
Cup No.	187
Mass Cup, g	0.0
Mass Dry Soil, g	20.4
% Moisture	25.0

PLASTIC LIMIT

Mass Cup + Wet Soil, g	32.8
Mass Cup + Dry Soil, g	28.2
Mass Water, g	4.6
Cup No.	188
Mass Cup, g	0.0
Mass Dry Soil, g	28.2
% Moisture	16.3

% Organic Matter (TR 413)	
Liquid Limit (TR 428)	24
Plasticity Index (TR 428)	8
Natural Moisture Content, % (TR 403)	
Optimum Moisture Content, % (TR 418)	16.0
Maximum Density, kg/m^3 (lb/ft^3) (TR 418)	1760
Laboratory Compaction Method (TR 418)	A
% Cement (TR 432 or Plans)	
% Lime (TR 416)	
% Fly Ash	
% Other (Additive) Material Code / Percent	
Soil Group (TR 423)	A-4 (2)
Classification (TR 423)	Clay Loam
pH (TR 430)	
Resistivity, ohm-cm (TR 429)	
Classification Prefix (TR 423) (G = Siliceous Aggr. N = Non-Siliceous S = Shell)	

(Required only if + 2.00 mm (No. 10) material equals or exceeds 5%)

Remarks 2

Tested By: G.C. Checked By: B.W. APPROVED BY:

Soils/Soil-Aggregate Worksheet – DOTD 03-22-0723
Figure A-1

DOTD 03-22-0752
Metric/English
Rev. 4/99

Louisiana Department of Transportation and Development

BASE COURSE DESIGN
FOR CENTRAL PLANT MATERIALS MIXTURES

Project No. 450-11-0002 Plant Code B201 Mat Code 421 Seq. No. 003

Plant Type 1 (1 = Batch, 2 = Continuous) Base Course Class ___ Base Course Type ________

FAP No. I-10-4(005) 117 Proj. Name Dutchtown - Sorrento

Proj. Engr. J. Crouse Contractor Atlas Constr.

Production Rate: ______ lb/batch ____ tons/hr ____ yd³/hr

Materials

	Code		Source		Batch Wt. (Batch Plant Oper.)	Feed Rate kg/min (lb/min) (Contin. Plant Oper.)	% Mass
MATERIAL 1	421	A-4(2)					91.6
MATERIAL 2							.
MATERIAL 3							.
CEMENT	1156	Type I	07361	Blue Circle			8.4
LIME/ADDITIVE							.
							100.0%

Gradation

Sieve Size	Material 1 ____, % % Passing	Material 2 ____, % % Passing	Material 3 ____, % % Passing	Contractor % Passing	DOTD % Passing
2 1/2					
1 1/2					
1					
3/4					
No. 4					
No. 10					
No. 40					
No. 200					

DOTD Results

Max. Dry Weight Density, kg/m³ *(lb/ft³)* 1805 Optimum Moisture, % 12.1 Cement, % 9.0

Unit Mass of Additive 1500 kg/m³ Lime, % .

Date First Used ___-___-___ Additive, % .

Remarks 1 ____________

Submitted By ____ ____________ Date ___-___-___

Checked By ____________ Date ___-___-___

Approved ____ *(yes / no)* Date ___-___-___

Approved By ____ ____________
District Laboratory Engineer - signature

Base Course Design For Central Plant Materials Mixtures – DOTD 03-22-0752
Figure A-2

DOTD Designation: TR 432-02

Method B – Soils With Less Than 5% Aggregate

I. Scope

This method is designed to determine the minimum percentage of cement for incorporation into soils with less than 5% aggregate by dry mass retained on a 4.75 mm (No. 4) sieve.

Note B-1: *Cement shall meet specifications for Type IB. For Type IB cement, a unit mass of 1500 kg/m³ shall be used.*

When either Type II or Type IP cement is used on the project, it shall be used in lieu of Type IB to determine the report values for this method of est. The cement used for this test procedure shall meet specifications. For Type II cement, a unit mass of 1500 kg/m³ (94 lb/ft³) shall be used. For Type IP cement, a unit mass of 1440 kg/m³ (90 lb/ft³) shall be used.

Note B-2: *When soil does not meet the specification requirements for cement stabilization or treatment, it shall not be tested to determine the percent cement.*

II. Apparatus

A. **Mold**
   1. A cylindrical metal mold, having a capacity of 0.000944 m³ (1/30 ft³), with an internal diameter of 101.60±0.41 mm (4.00±0.016 in.) and height of 116.43±0.13 mm (4.584±0.005 in.), and with a detachable collar approximately 64 mm (2.5 in.) in height, which can be fastened firmly to a base plate.
   2. Molds shall be replaced if any diameter is more than 102.21 mm (4.024 in.) or the height is less than 115.57 mm (4.550 in.) at any point.

Note B-3: *Different makes of compactive devices may use mold base plates of different designs. The mold base plate must be compatible with the make of compactive device used.*

B. **Compactive Device**
   1. Automatic Rammer – A metal 2.495±0.023 kg (5.50±0.05 lb) rammer, with a striking face that is a 2026.83 mm² sector face for use with a 101.60 mm (4.000 in.) inside diameter mold and arranged to control the height of drop to 305±2 mm (12±0.06 in.).
   2. Manual Rammer – A metal 2.495±0.023 kg (5.50±0.05 lb) rammer with a circular striking face with a diameter of 50.80±0.025 mm (2.00±0.01 in.) and arranged to control the height of drop to 305±2 mm (12±0.06 in.).

C. **Compaction block** – a stable block or pedestal composed of portland cement concrete having a minimum mass of 90 kg (200 lb).

D. **Straightedge** – a steel straightedge, approximately 300 mm (12 in.) long.

E. **Scale** – a scale with a minimum of 10 kg capacity, readable to 1 g.

F. **Sieve** – a 4.75 mm (No. 4) sieve conforming to the requirements of AASHTO M92.

G. **Tools**
   1. Mixing pans with air-tight covers.
   2. Spoons.
   3. Pointed trowel.
   4. Spatula or large suitable mechanical device for thoroughly mixing the soil with water.
   5. Large screwdriver to remove material from mold

H. **Graduated cylinders** – incremented in mL.
I. **Sealable containers.**
J. **Wax paper.**
K. **Specimen ejector** a closed cylindrical sleeve slightly less than 102 mm (4 in.) in diameter or a piston of the same diameter, actuated mechanically, hydraulically or by air pressure (Figure B-1).
L. **Moist room** – capable of maintaining not less than 90% relative humidity and a temperature of 23±1.7°C.
M. **Height gauge** – capable of measuring to 0.01 mm (0.001 in.).
N. **Compression device** – meeting the specifications of ASTM D 1633. Screw powered devices shall be set so that the rate of loading for the compression test corresponds with the moving head operating at approximately 1.3 mm/min (0.05 in./min.) when the device is running idle. Hydraulic devices hall be set so that the loading rate is within 140±50 kPa/sec (20±10psi).
O. **Scarifier** – capable of scarifying soil specimens, with prongs approximately 3 mm (1/8 in.) wide and 6 mm (1/4 in.) apart.
P. **Cement** – portland or portland-pozzolan cement meeting DOTD specifications for the type of cement.
Q. **Waterproof black ink marker.**
R. **Porous stones** – equal to or larger than the diameter of the specimen, stored in moist room on a continuous basis to ensure saturated condition.
S. **Engineer's curve** – Alvin 1010-21 or equivalent.
T. **Additive Conversion Chart** (Figure B-2).
U. **Mix design worksheet** – Soil Cement Mix Design Worksheet, DOTD Form No. 03-22-0757 (Figure B-3, Front & Back).
V. **Worksheet** – Soils/Soil-Aggregate, DOTD Form No. 03-22-0723.

III. Sample

Obtain a representative sample of the material to be stabilized or treated weighing at least 80 kg (180 lb).

IV. Procedure

A. Sample Preparation
1. Prepare sample in accordance with DOTD TR 411M. Discard any material retained on the 4.75 mm (No. 4) sieve.
2. Determine the moisture-density relationships of the material in accordance with either DOTD TR 415M – Method A or the appropriate method of DOTD TR 418M. If the soil is to be treated or conditioned prior to stabilization, add the proper percentage of additive to the portion of the sample to be used in DOTD TR 418M – Method B. Record optimum moisture as DB and maximum dry mass density as DC on the mix design worksheet.

Note B-4: *When the soil contains less than 20% clay (primarily sandy and/or silty particles), or is moisture sensitive (steep moisture density curve), and the laboratory has limited experience with the material, it may be necessary to start at this point in the test procedure with the optimum moisture from a cement curve compacted with 10% cement by mass. The optimum moisture content thus determined will be used as the Design Moisture (DM).*

Note B-5: *If moisture-density relationships are determined by DOTD TR 418M – Method H and the* *recycled material contains less than 5% retained on the 4.75 mm (No. 4) sieve, a 0.0009444 mm³ (1/30 ft³) mold may be used.*

3. Determine the design moisture content in accordance with Step V.A. and record as DM on the mix design worksheet.
4. Place the remaining prepared material in the oven and dry to constant mass in accordance with DOTD TR 403 and TR 411M to eliminate the effects of hygroscopic moisture.

Note B-6: *Hygroscopic moisture is moisture which an unprotected oven-dried soil absorbs from the air.*

5. Remove the dried material from the oven within 24 hours of beginning specimen preparation. Protect the material from moisture contamination from the air during its cooling period by placing it in sealed containers before water absorption begins.

B. Specimen Preparation
1. If the soil is to be treated or conditioned prior to stabilization, add the proper percentage of the additive to the dried soil and mix thoroughly.
2. Place exactly 2300 g of the material in each of 20 separate mixing pans, in order to produce four sets of five specimens.
3. Determine the quantity of water needed to bring each 2300-g portion to the slaked moisture content (5% below design moisture content) in accordance with Step V.B. Record on the mix design worksheet as slake water (M).
4. Add the proper quantity of slake water to each 2300-g portion and mix thoroughly. Record the time of each water addition on the worksheet.
5. Cover each 2300-g portion to which slake water has been added, protect them so that the moisture content remains constant, and allow them to slake for a minimum of 30 minutes for raw soils, a minimum of 15 hours for lime-treated or conditioned soils, or a minimum of 12 hours for recycled materials.

Note B-7: *Stagger the timing of the addition of cement and net water quantity (Steps IV.B.6 and 7) to meet the time limitations of Step IV.B.8.*

6. Incorporate 6%, 9%, 12%, and 15% cement by mass into the 4 sets of specimens by adding the quantity of cement in grams shown on the mix design worksheet. Mix thoroughly.
7. Immediately add the proper quantity of net water to each test specimen and mix thoroughly. Record the time of each water addition on the mix design worksheet.
8. Cover and protect the individual test specimens so that the moisture content remains constant, then allow them to stand for at least 60 minutes. Time the beginning of molding test cylinders to ensure that the molding of test specimens will be completed within 90 minutes of the addition of cement. Record the time of molding on the mix design worksheet.

C. Molding and Curing Test Cylinders

Note B-8: *In order to have adequate time to complete all requirements of this procedure within normal working hours, the molding of test cylinders must begin as near the start of the workday as possible.*

1. If mold requires an attachable base plate, attach base plate.
2. When using a mold without an attachable base plate, place wax paper on the compactor base. Place the mold over the wax

paper and secure the mold to the compactor base.

3. Attach the collar to the mold.
4. Uncover one test specimen. Remix the material. Place a quantity of the test specimen into the mold in an even layer that will yield slightly more than 1/3 the volume of the mold after compaction. Recover the test specimen to protect material remaining in the pan.
5. Use a pointed trowel to rearrange particles, filling voids in the loose material without compacting the material.
6. Rest the rammer on top of the layer to be compacted. Compact the layer using 25 blows of the rammer.
7. Note height of compacted material. If compacted layer is not 1/3 the height of the mold, correct for any deviation by adjusting the quantity of material used for the subsequent layer.
8. Using the scarifier, scratch the surface of the compacted layer with grooves approximately 3 mm wide, 3 mm deep, and 6 mm apart (1/8 in. by 1/8 in. by ¼ in.), perpendicular to each other, to remove smooth compaction planes.
9. Repeat Steps IV.C.4 – 8 for two more layers, scarifying only the intermediate layer.
10. After the third layer has been compacted, place the mold, base plate (if applicable), and compacted specimen in a pan.
11. Tap the collar with the straightedge to loosen material bond and remove the collar from the mold without twisting or causing shear stress to the molded specimen.
12. Note the height of the compacted test specimen. If it is greater than 6½ mm (1/4 in.) above the top of the mold or is below the lip of the mold, remove the cylinder from the mold, remix and remold the material.
13. Keeping the mold, base plate (if applicable), and specimen in the pan, use the straightedge to trim the specimen even with the top of the mold.
14. Fill any depressions with the trimmed material. After the depressions are filled, smooth with the straightedge even with the top of the mold.
15. Brush material from all outside surfaces of the mold and exposed edges of base plate or wax paper. Remove wax paper (if applicable).
16. Eject the test specimen from the mold, utilizing the specimen ejector. Assign a laboratory identification to the specimen and mark it on the specimen using the black marker or a tag. Do not scar or deform the specimen.
17. Invert specimen on a porous stone, immediately protect it from moisture loss, and place it in the moist room. Protect the specimen from direct spray in the moist room.
18. Repeat Steps IV.C. 1 – 17 for the other test specimens at the same cement content.
19. Repeat Steps IV. C. 1 – 18 for all other test specimens at the remaining cement contents.
20. Allow the specimens to remain in the moist room for 7 days.

D. Testing Specimens

1. Remove the specimens from the moist room.

Note B-9: *Protect specimens from moisture loss between removal from the moist room and breaking.*

2. Place the specimen on the lower bearing block of the testing machine, making certain that the vertical axis of the specimen is aligned with the center of thrust of the spherically seated upper bearing block. Raise the lower

block until the specimen comes into contact with the upper block, aligning the upper block in order to obtain uniform seating (if applicable to the testing device).

3. Immediately apply load continuously, at the rate specified in Step II.N, without shock until the reading stabilizes or falls. Continue loading for approximately 10 – 15 seconds.
4. Record the failure load (load at which the reading stabilized or peaked) as Z, to the nearest graduation shown on the dial.
5. Remove the specimen from the machine. Grasp the top and bottom of the specimen and slowly twist in opposite directions. Record the type of break obtained as indicated on the worksheet.

Note B-10: *If the compression device requires a calibration chart to convert dial readings to failure load, record the dial reading and its corresponding failure load (Z) on the worksheet.*

6. Repeat Steps 2 – 5 for each specimen. Break all 4 sets of test specimens within 90 minutes from the time that the first cylinder is removed from the moist room.

E. Determination of Compressive Strength
   1. Discard the highest and lowest failure loads (Z) (recorded in Step D.4) for each percent cement.
   2. Determine the compressive strength of each of the three remaining test specimens at each percent cement in accordance with Step V.C., and record as P on the mix design worksheet.

Note B-11: *If the type of break recorded indicates an irregular failure pattern, the compressive strengths of these specimens should be analyzed to determine their suitability to be used in the average compressive strength for that set of specimens. Additional specimens may be necessary.*

   3. Determine the average compressive strength for each percent cement in accordance with Step V.D. Record as Q on the mix design worksheet.

F. Determination of Curve Cement Factor
   1. Label the vertical axis of the graph on the worksheet with a range of compressive strengths that includes the average compressive strengths of each set determined in Step E.3.
   2. Plot the average compressive strength for each corresponding cement content.
   3. Draw a straight line connecting the points immediately above and below the design compressive strength line. (Refer to Introduction for design compressive strength.)
   4. Select the point at which the design compressive strength line intersects the line drawn in Step 3. This percent cement will be recorded to the nearest 0.1% on the Soil Cement Mix Design Worksheet as Curve Cement Factor.

G. Determination of Minimum Cement Factor
   1. To determine the minimum cement factor by mass, if the Curve Cement Factor is other than a whole percent, round it to the next whole percent and report as minimum Cement Factor by Mass on the mix design worksheet. If the Curve Cement Factor is a whole percent, report the Curve Cement Factor as Minimum Cement Factor by Mass.
   2. Determine the minimum cement factor by volume in accordance

with Step V.E., using the Curve Cement Factor.

V. Calculations

A. Calculate the design moisture content (DM) to the nearest 0.1% using the following formula:

$$DM = DB + V$$

where:

DB = optimum moisture content for raw or lime treated material, %
V = constant (1.0% for A-4, A-6 or lime treated soils and 0.5% for other soils)

example:

DB = 12.1
V = 1.0

$$DM = 12.1 + 1.0$$
$$DM = 13.1$$

B. Calculate the slake water (M), the quantity of water needed to bring each test specimen to the slaked moisture content, to the nearest mL using the following formula:

Note B-12: *1 g water = 1 mL water*

$$M = K \times \left(\frac{DM - 5}{100}\right)$$

where:

K = mass of test specimen, g
DM = design moisture content, %
5 = constant, represents reduction in % design moisture
100 = constant, %

example:

K = 2438
DM = 13.1

$$M = 2438 \times \left(\frac{13.1 - 5}{100}\right)$$

$$= 2438 \times \left(\frac{8.1}{100}\right)$$
$$= 2438 \times (0.081)$$
$$= 197.47$$
$$M = 197$$

C. Calculate the compressive strength (P) of each test specimen to the nearest 10 kPa (psi) using the following formula:

METRIC:

$$P = \frac{Z}{0.0081}$$

where:

Z = failure load, kN
0.00081 = constant, cross sectional area of specimen, m^2

example:

Z = 22.29

$$P = \frac{22.29}{0.0081}$$

$$P = 2751.85$$
$$P = 2750$$

ENGLISH:

$$P = \frac{Z}{12.6}$$

where:

Z = failure load, lb
12.6 = constant, cross sectional area of specimen, in²

example:

Z = 5010

$$P = \frac{5010}{12.6}$$

$$P = 397.61$$
$$P = 398$$

D. Calculate the average compressive strength (Q) to the nearest 10 kPa (psi) using the following formula:

$$Q = \frac{P_1 + P_2 + P_3}{3}$$

where:

P_1, P_2, P_3 = comp. str. of the 3 individual test spec.
3 = constant, number of specimens

example:

METRIC:

P_1 = 2750
P_2 = 2680
P_3 = 2760

$$Q = \frac{2750 + 2680 + 2760}{3}$$

$$= \frac{8190}{3}$$
$$= 2730$$

ENGLISH:

P_1 = 398
P_2 = 375
P_3 = 390

$$Q = \frac{398 + 375 + 390}{3}$$

$$= \frac{1163}{3}$$
$$= 387.66$$
$$Q = 388$$

E. Calculate the minimum cement factor by volume by using the Additive Conversion chart. This chart may be used for Type I, IB, or II portland cement.
1. Enter the chart on the left scale. Reading vertically, place a point at the appropriate maximum dry mass density (DC) of the raw soil on the mix design worksheet.
2. Reenter the chart on the cement (center) scale. Reading vertically, place a point at the Curve Cement Factor percent.
3. Draw a straight line across the chart connecting the two points plotted in Steps 1 and 2, extending the line to intersect with the Cement Percent By Volume (right) scale.
4. Read the percent by volume directly from the right scale where the line intersects the right scale.
5. Round any partial percent to the next higher whole percent. Record this value as minimum cement factor by volume on the mix design worksheet.
6. Example: *Type IB Cement, Figure B-2*

A = 1760 kg/m³ (110 lb/ft³)
Curve Cement Factor = 6.5%

(1) Follow the left scale to the point represented by 1760 kg/m^3 (110 lb/ft^3)
(2) Follow the center scale to the point represented by 6.5% by mass
(3) Draw a straight line across the scale, connecting the two points and extending it to intersect the right scale.
(4) The percent cement by volume, read directly from the right scale, is 7.1%.
(5) Round 7.1% to 8% and record.

7. In lieu of the charts or if values are not covered by the charts, calculate the percent by volume of cement (V) to the nearest percent using the following formula:

$$V = \frac{DC}{[(\frac{1}{R}) + 0.01] \times U}$$

where:

DC = max. dry wt. density of the soiloil, kg/m^3 (lb/ft^3)
U = unit wt of additive, kg/m^3 (lb/ft^3)
R = Curve Cement Factor, %
0.01 = constant
1 = constant

example: *Type IP Cement*

METRIC:

DC = 1760
R = 6.5
U = 1440

$$V = \frac{1760}{[(\frac{1}{6.5}) + 0.01] \times 1440}$$

$$= \frac{1760}{(0.15 + 0.01) \times 1440}$$

$$= \frac{1760}{0.16 \times 1440}$$

$$= \frac{1760}{230.40}$$

$$= 7.63$$

$$V = 8$$

ENGLISH:

DC = 110
R = 6.5
U = 90

$$V = \frac{110}{[(\frac{1}{6.5}) + 0.01] \times 90}$$

$$= \frac{110}{(0.15 + 0.01) \times 90}$$

$$= \frac{110}{0.16 \times 90}$$

$$= \frac{110}{14.40}$$

$$= 7.63$$

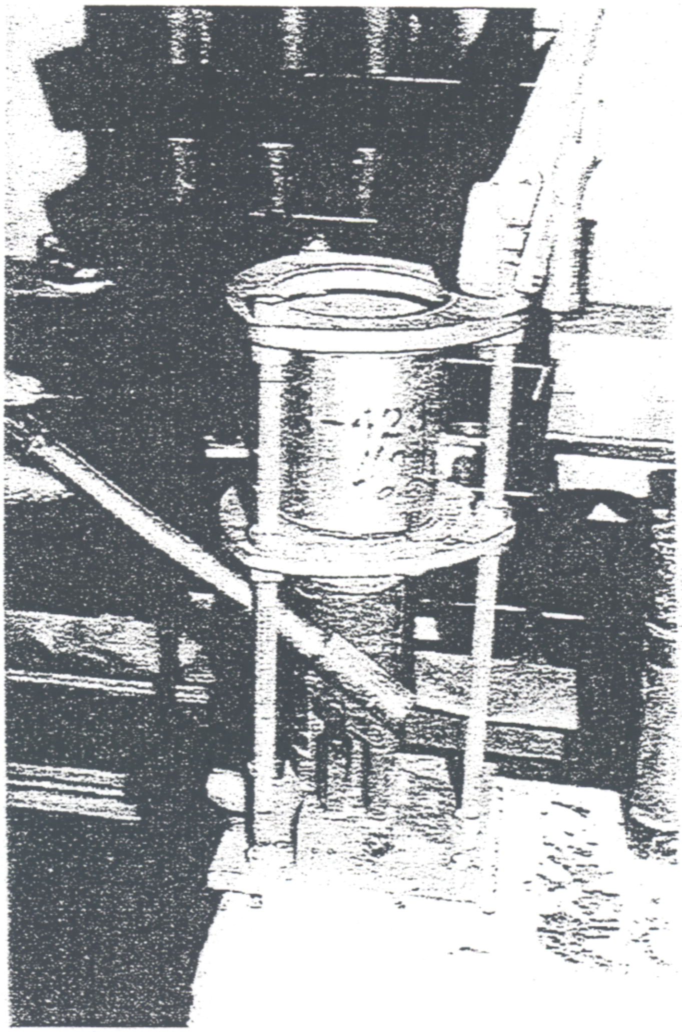
$$V = 8$$

VI. Report

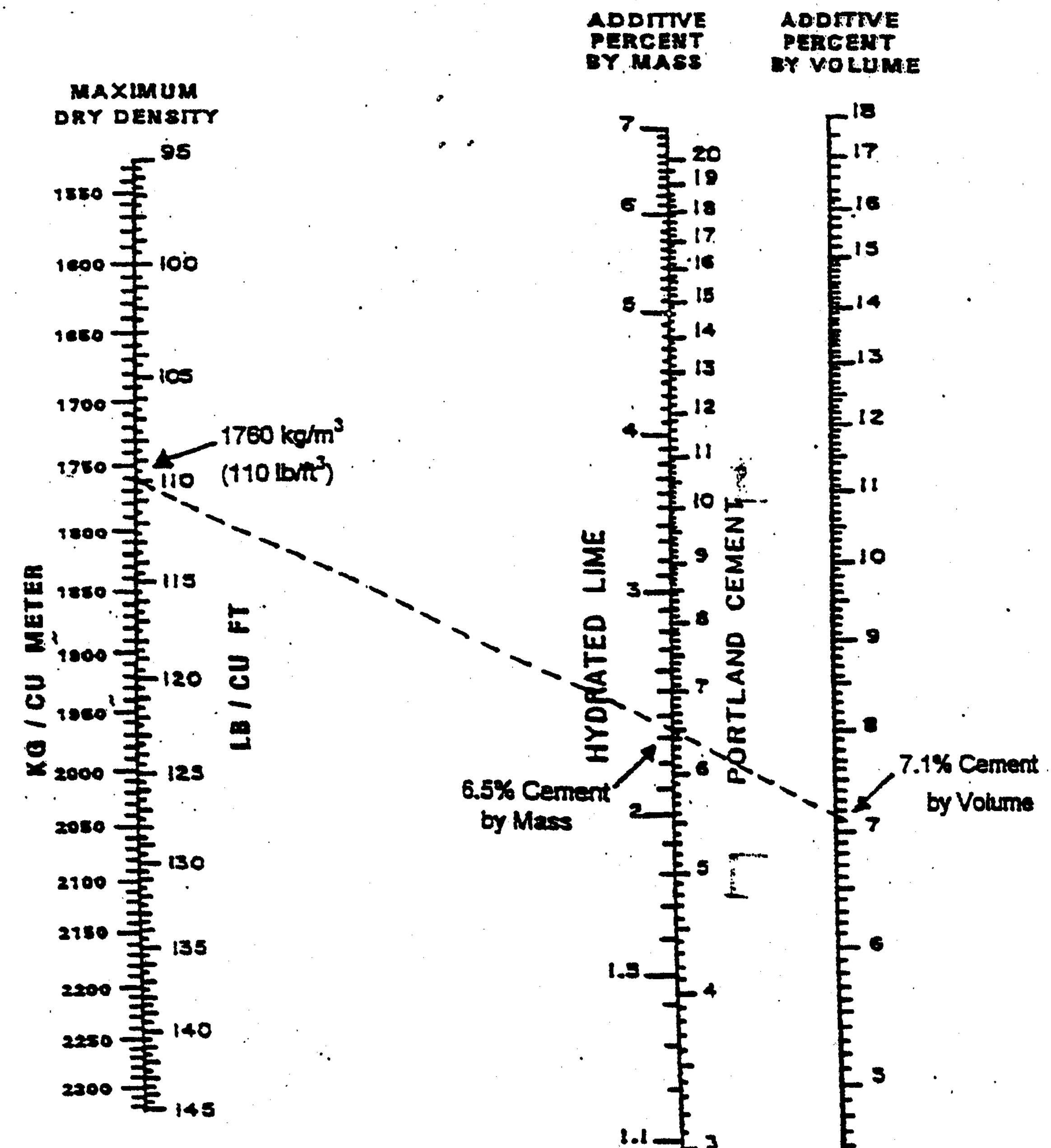
Report the minimum cement factor by volume or by mass as applicable to the specification item.

VII. Normal Test Reporting Time

Normal test reporting time is a maximum of 21 days, including the completion of all prerequisite testing.



Specimen Ejector
Figure B-1



Note: *This chart is not suitable for use when Type IP Portland-Pozzolan Cement is being used.*

ADDITIVE CONVERSION CHART

RELATION IN PERCENT BY MASS OF OVEN-DRY SOIL, SOIL-AGGREGATE, OR AGGREGATE TO DESIGN PERCENT BY VOLUME

Additive Conversion Chart
Figure B-2

SOIL-CEMENT MIX DESIGN WORKSHEET

DOTD TR 432 METHODS B & C

DOTD 03-22-0757
Metric/English
Rev. 4/99

PROJECT NO.: 450-11-0002 COMPOSITE NO(S).: ______ SAMPLE NO.: SC 1 LAB NO.: 22-456789

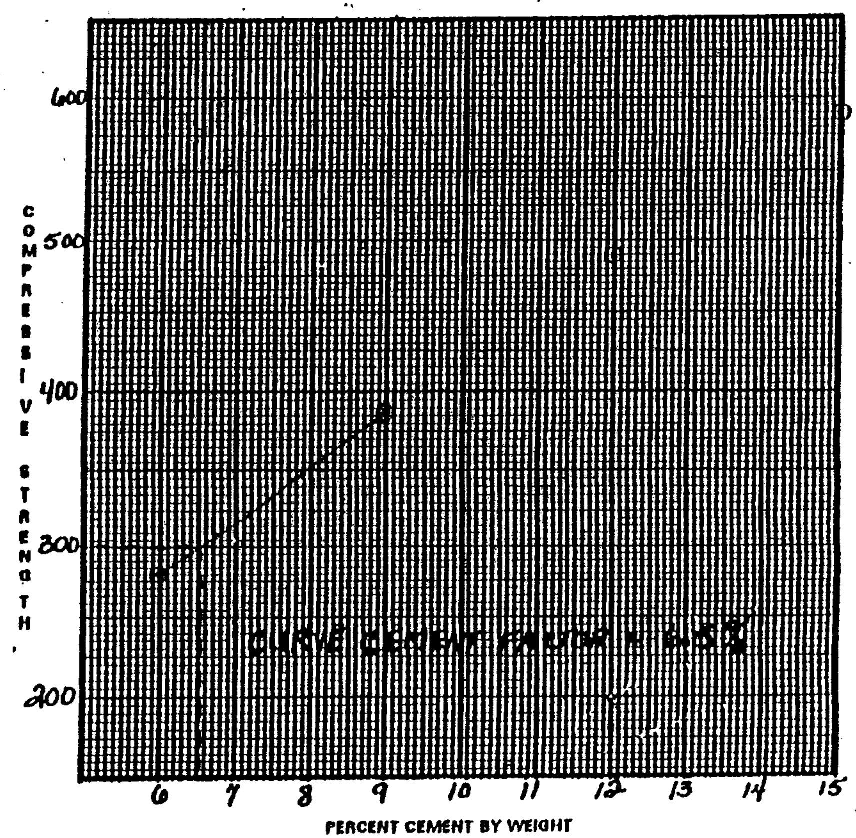
TYPE SOIL: Clay Loam DATE MOLDED: 3/16/99 TESTED BY: D.B. CHECKED BY: L.C.

BREAK DATE: 3/23/99 MIN. CEM. FACTOR: 7 % By Mass (Wt) 8 % By Vol. OPT. MOIST.,% ______ MAX. DWD ______

(Cement Stabilized or Treated Material)

COMPRESSION TEST DATA

Cylinder Number	% Cem't by Wt.	Break Code	Dial Reading	Failure Load (Z) (kN or Lb)	Compressive Strength (P) (MPa or PSI)	Average Compressive Strength (Q) (MPa or PSI)
A-1	6	1		3655	290	280
A-2		1		4540		
A-3		1		3340	265	
A-4		1		3590	285	
A-5		2		2930		
B-1	9	1		5010	398	388
B-2		1		4725	375	
B-3		2		3020		
B-4		1		4915	390	
B-5		1		5730		
C-1	12	1		6650		490
C-2		1		6110	485	
C-3		1		6615	525	
C-4		2		5630		
C-5		2		5795	460	
D-1	15	1		7520		590
D-2		1		7495	595	
D-3		1		6815		
D-4		1		7310	580	
D-5		1		7495	595	



REMARKS: ______

TYPE OF BREAK 1 = Regular 2 = Irregular

DESCRIPTION

Soil Cement Mix Design Worksheet, DOTD 03-22-0757
Figure B-3 (Front) *English*

SOIL-CEMENT MIX DESIGN WORKSHEET
DOTD TR 432 METHODS B & C

DOTD 03-22-0757
Metric/English
Rev. 4/99

PROJECT NO.: 450-11-0002 COMPOSITE NO(S).: ______ SAMPLE NO.: SC-1 LAB NO.: 22456789

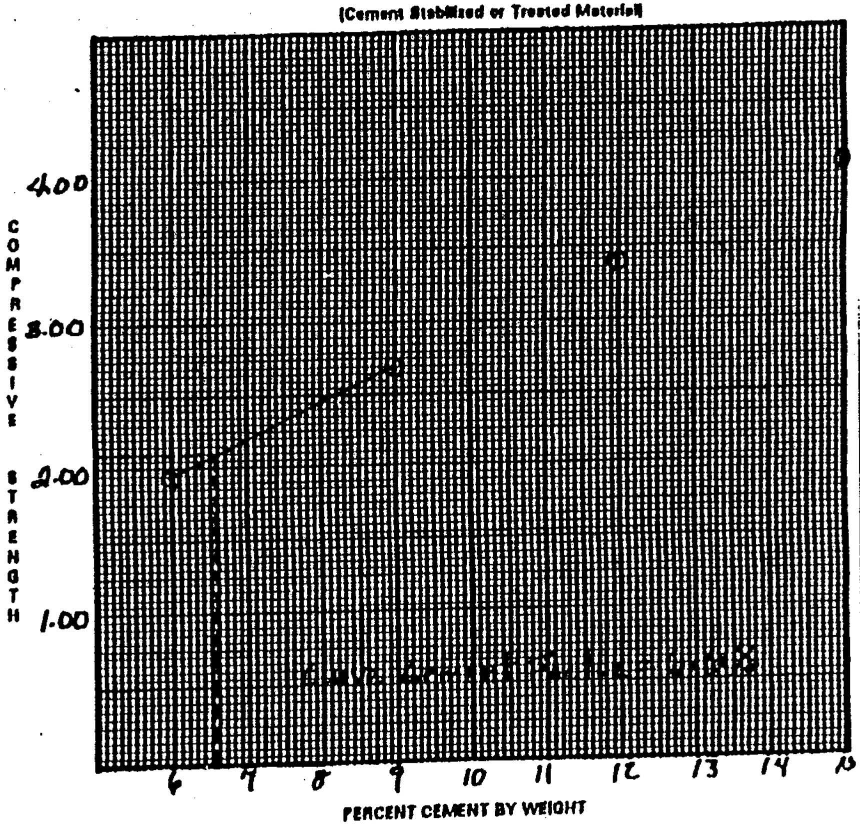
TYPE SOIL: Clay Loam DATE MOLDED: 04-06-99 TESTED BY: D.B. CHECKED BY: L.C.

BREAK DATE: 04-13-99 MIN. CEM. FACTOR: 7 % By Mass (Wt) 8 % By Vol. OPT. MOIST., % ______ MAX. DWD ______

COMPRESSION TEST DATA

Cylinder Number	% Cem't by Mass (Wt)	Break Code	Dial Reading	Failure Load (Z) (kN or Lb)	Compressive Strength (P) (MPa or PSI)	Average Compressive Strength (Q) (MPa or PSI)
A-1		1		16.25	2.01	
A-2		1		20.19		
A-3	[illegible]	1		14.86	1.83	1.94
A-4		1		15.96	1.97	
A-5		2		13.03		
B-1		1		22.28	2.75	
B-2		1		21.02	2.59	
B-3	[illegible]	2		18.43		2.68
B-4		1		21.86	2.70	
B-5		1		25.49		
C-1		1		29.58		
C-2		1		27.19	3.36	
C-3	12	1		29.42	3.63	3.39
C-4		2		25.04		
C-5		2		25.78	3.18	
D-1		1		33.46		
D-2		1		33.34	4.12	
D-3	16	1		30.81		4.08
D-4		1		32.62	4.01	
D-5		1		33.84	4.12	

REMARKS: ______



TYPE OF BREAK 1 = Regular 2 = Irregular

DESCRIPTION

Soil Cement Mix Design Worksheet, DOTD 03-22-0757
Figure B-3 (Front) *Metric*

SOIL CEMENT DESIGN CALCULATIONS
DOTD TR 432 - METHODS B & C

OPTIMUM MOISTURE AND DESIGN MOISTURE

Soil Group (TR 423) A-4 (2)

Classification (TR 423) Clay Loam

Optimum Moisture Content of Material (DB) = 12.1 %

Design Moisture Content (DM = DB + V) = 13.1 %

Max. Dry Density of Material (DC) = 1760

(DOTD TR 415 ____ DOTD TR 418 ✓)

For A-4 and A-6 Soils, V = 1.0%
For all other soils, V = 0.5%

METHOD B

% Cement (by wt.)	Dry Weight of Material (g)	Cement (g)	Material + Cement (g)	Evap (mL)	Slake Water (mL)	Slake Time	Net Water (mL)	Net Water Time	Molding Time
H	I	J	K	L	M		N		
					K x (DM -5)/100		L + 0.05K		
6	2300	138	2438	24	197	8:45	146	9:15	10:15
9		207	2507	25	203	10:00	150	10:30	11:30
12		276	2576	26	209	11:15	155	11:45	12:45
15		345	2645	26	214	12:30	158	1:00	2:00

METHOD C

% Cement (by wt.)	Dry Weight of Material (g)	Cement (g)	Material + Cement (g)	Evap (mL)	Slake Water (mL)	Slake Time	Net Water (mL)	Net Water Time	Molding Time
H	I	J	K	L	M		N		
					K x (DM -5)/100		L + 0.05K		
6	6300	378	6678	67			401		
9		567	6867	69			412		
12		758	7058	71			424		
15		945	7245	72			434		

Soil Cement Mix Design Worksheet, DOTD 03-22-0757
Figure B-3 (Back)

DOTD Designation: TR 432-02

Method C – Soils With 5% or More Aggregate

I. Scope

This method is designed to determine the minimum percentage of cement for incorporation into soil-aggregates with 5% or greater aggregate by dry mass retained on a 4.75 mm (No. 4) sieve, recycled in-place soil-aggregates, shell, sand-shell, or sand clay gravel.

Note C-1: *Cement shall meet specifications for Type IB. For Type IB cement, a unit mass of 1500 kg/m³ (94 lb/ft³) shall be used.*

When either Type II or Type IP cement is used on the project, it shall be used in lieu of Type IB to determine the report values for this method of test. The cement used for this test procedure shall meet specifications. For Type II cement, a unit mass of 1500 kg/m³ (94 lb/ft³) shall be used. For Type IP cement, a unit mass of 14400 kg/m³ (90 lb/ft³) shall be used.

Note C-2: *When soil does not meet the specification requirements for cement stabilization or treatment, it shall not be tested to determine the percent cement.*

II. Apparatus

A. **Mold**

1. A cylindrical metal mold, having a capacity of 0.002832 m³ (1/10 ft³), with an internal diameter of 152.46±0.66 mm (6.000±0.026 in.) and a height of 154.90±0.41 mm (6.100±0.016 in.), and with a detachable collar approximately 89 mm (3.5 in.) in height, which can be fastened firmly to a base plate.
2. Molds shall be replaced if any diameter is more than 153.39 mm (6.039 in.) or the height is less than 152.40 mm (6.000 in.) at any point.

Note C-3: *Different makes of compactive devices may use mold base plates of different designs. The mold base plate must be compatible with the make of compactive device used.*

B. **Compactive Device**

1. Automatic Rammer
   a. A metal 4.536±0.045 kg (10.0±0.1 lb) rammer, with a striking face that is a 2026.83 mm² (3.1416 in.²) sector face for use with a 152.46 mm (6 in.) inside diameter mold and arranged to control the height of drop to 457±2 mm (18±0.06 in.).
   b. Alternate – a metal 2.495±0.023 kg (5.50±0.05 lb) rammer, with a striking face that is 2026.83 mm³ (3.1416 in.²) sector face for use with a 152.46 mm (6 in.) inside diameter mold and arranged to control the height of drop to 305±2 mm (12±0.06 in.).
2. Manual rammer
   a. A metal 4.536±0.045 kg (10.0±0.1 lb) rammer with a circular striking face with a diameter of 50.8 mm (2.00±0.01 in.) and arranged to control the height of drop to 457±2 mm (18±0.06 in.).
   b. Alternate – a metal 2.495±0.023 kg (5.50±0.05 lb) rammer, with a circular striking face with a diameter of 50.8 mm (2.00±0.01 in.)

and arranged to control the height of drop to 305±2 mm (12±0.06 in.).

C. **Compaction block** – a stable block or pedestal composed of portland cement concrete weighing a minimum of 90 kg (200 lb).
D. **Straightedge** – a steel straightedge, approximately 300 mm (12 in.) long.
E. **Scale** – a scale with a minimum of 10 kg capacity, readable to 1 g.
F. **Sieves** – 25.0 mm, 19.0 mm, 12.5 mm and 4.75 (1 in., ¾ in., ½ in., and No. 4) sieves conforming to the requirements of AASHTO M 92.
G. **Tools**
   1. Mixing pans with air-tight covers.
   2. Spoons.
   3. Pointed trowel.
   4. Spatula or large suitable mechanical device for thoroughly mixing the soil with water.
   5. Large screwdriver to remove material from mold.
H. **Graduated cylinders** – incremented in mL.
I. **Sealable containers.**
J. **Wax paper.**
K. **Specimen ejector** – a closed cylindrical sleeve slightly less than 152.4 mm (6.0 in.) in diameter or a piston of the same diameter, actuated mechanically, hydraulically or by air pressure. (Figure B-1)
L. **Moist room** – capable of maintaining not less than 90% relative humidity and a temperature of 23±1.7°C (73.4±3°F).
M. **Height gauge** – capable of measuring to 0.01 mm (0.001 in.)
N. **Compression device** – meeting the specifications of ASTM D 1633. Screw powered devices shall be set so that the rate of loading for the compression test corresponds with the moving head operating at approximately 1.3 mm/min (0.05 in./min) when the device is running idle. Hydraulic devices shall be set so that the loading rate is within 140±5 kPa/sec (20±10 psi/sec).
O. **Scarifier** – capable of scarifing soil specimens, with prongs approximately 3 mm (1/8 in.) wide and 6 mm (1/4 in.) apart.
P. **Cement** – portland or portland-pozzolan cement meeting specifications for the type of cement.
Q. **Waterproof black ink marker.**
R. **Porous stones** – equal to or larger than the diameter of the specimen, stored in moist room on a continuous basis to ensure saturated condition.
S. **Engineer's curve** – Alvin 1010-21 or equivalent.
T. **Additive Conversion Chart** – (Figure C-1).
U. **Mix design worksheet** – Soil Cement Mix Design Worksheet, DOTD Form No. 03-22-0757. (Figure C-2, Front & Back).
V. **Worksheet** – Soils/Soil-Aggregate, DOTD Form No. 03-22-0723.

III. Sample

Obtain a representative sample weighing at least 82 kg (600 lb).

IV. Procedure

A. Sample Preparation
   1. Prepare sample in accordance with DOTD TR 411M, using 25.0 mm, 19.0 mm, 12.5 mm, and 4.75 mm (1 in., ¾ in., ½ in., and No. 4) sieves. Prorate the aggregate in accordance with the appropriate method of DOTD TR 418M. If DOTD TR 415M will be used to determine the moisture-density relationships of the material (as allowed by DOTD TR 418M), process the sample in accordance with procedure outlined in DOTD TR 415M.
   2. Determine the moisture-density relationships of the material in accordance with either DOTD TR 415M – Method A or the appropriate method of DOTD TR 418M. If the material is to be

conditioned prior to stabilization, add the proper percentage of additive to the portion of the sample to be used in DOTD TR 418M – Method B. Record optimum moisture as DB and maximum dry mass density as DC on the mix design worksheet.

Note C-4: *When the soil contains less than 20% clay (primarily sandy and/or silty particles), or is moisture sensitive (steep moisture density curve), and the laboratory has limited experience with the material, it may be necessary to start at this point in the test procedure with the optimum moisture from a cement curve compacted with 10% cement by mass. The optimum moisture content thus determined will be used as the design Moisture (DM).*

3. Determine the design moisture content in accordance with Step V.A. and record as DM on the mix design worksheet.
4. Place the remaining prepared material in the oven and dry to constant mass in accordance with DOTD TR 403 and TR 411M to eliminate the effects of hygroscopic moisture.

Note C-5: *Hygroscopic moisture is moisture which an unprotected oven-dried soil absorbs from the air.*

5. Remove the dried material from the oven within 24 hours of beginning specimen preparation. Protect the material from moisture contamination from the air during its cooling period by placing it in sealed containers before water absorption begins.

B. Specimen Preparation
1. If the material is to be treated or conditioned prior to stabilization, add the proper percentage of the additive to the dried soil and mix thoroughly.
2. Place exactly 6300 g of the material in each of 20 separate mixing pans, in order to produce four sets of five specimens.
3. Determine the quantity of water needed to bring each 6300-g portion to the slaked moisture content (5% below design moisture content) in accordance with Step V.B. Record on the mix design worksheet as slake water (M).
4. Add the proper quantity of slake water to each 6300-g portion and mix thoroughly. Record the time of each water addition on the worksheet.
5. Cover each 6300-g portion to which slake water has been added, protect them so that the moisture content remains constant, and allow them to slake for a minimum of 30 minutes for raw soils, a minimum of 15 hours of lime-treated or conditioned soils, or 12 hours for recycled materials.

Note C-6: *Stagger the timing of the addition of cement and net water quantity (Steps IV.B.6 and 7) to meet the time limitations of Step IV.B.8.*

6. Incorporate 6%, 9%, 12%, and 15% cement by mass into the 4 sets of specimens by adding the quantity of cement in grams shown on the mix design worksheet. Mix thoroughly.
7. Immediately add the proper quantity of net water to each test specimen and mix thoroughly. Record the time of each water addition on the mix design worksheet.
8. Cover and protect the individual test specimens so that the moisture content remains constant, then allow them to stand for at least 60 minutes. Time the beginning of molding test cylinders to ensure that the

molding of test specimens will be completed within 90 minutes of the addition of cement. Record the time of molding on the mix design worksheet.

C. Molding and Curing Test Cylinders

Note C-7: *In order to have adequate time to complete all requirements of this procedure within normal working hours, the molding of test cylinders must begin as near the start of the workday as possible.*

1. If mold requires an attachable base plate, attach base plate.
2. When using a mold without an attachable base plate, place wax paper on the compactor base. Place the mold over the wax paper and secure the mold to the compactor base.
3. Attach the collar to the mold.
4. Uncover one test specimen. Remix the material. Place a quantity of the test specimen into the mold in an even layer that will yield slightly more than 1/3 the volume of the mold after compaction. Recover the test specimen to protect material remaining in the pan.
5. Use a pointed trowel to rearrange particles, filling voids in the loose material without compacting the material.
6. Rest the rammer on top of the layer to be compacted. Compact the layer using 28 blows with the 4.536 kg (10 lb) rammer, with a 457 mm (18-in.) drop [alternate 75 blows with the 2.495 kg (5.5 lb) rammer, with a 305 mm (12-in.) drop].
7. Note height of compacted material. If compacted layer is not 1/3 the height of the mold, correct for any deviation by adjusting the quantity of material used for the subsequent layer.
8. Using the scarifier, scratch the surface of the compacted layer with grooves approximately 3 mm by 3 mm by 6 mm apart (1/8 in. wide, 1/8 in. deep, and ¼ in.), perpendicular to each other, to remove smooth compaction planes.
9. Repeat Steps IV.C.4 – 8 for two more layers, scarifying only the intermediate layer.
10. After the third layer has been compacted, place the mold, base plate (if applicable), and compacted specimen in a pan.
11. Tap the collar with the straightedge to loosen material bond and remove the collar from the mold without twisting or causing shear stress to the molded specimen.
12. Note the height of the compacted test specimen. If it is greater than 12.70 mm (0.50 in.) above the top of the mold or is below the lip of the mold, remove the cylinder from the mold, remix and remold the material.
13. Keeping the mold, base plate (if applicable), and specimen in the pan, use the straightedge to trim the specimen even with the top of the mold.
14. Fill any depressions with the trimmed material. After the depressions are filled, smooth with the straightedge even with the top of the mold.
15. Brush material from all outside surfaces of the mold and exposed edges of base plate or wax paper. Remove wax paper (if applicable).
16. Eject the test specimen from the mold, utilizing the specimen ejector. Assign a laboratory identification to the specimen and mark it on the specimen using the black marker or a tag. Do not scar or deform the specimen.
17. Invert specimen on a porous stone, immediately protect it from moisture loss, and place it in the moist room. Protect the specimen from direct spray in the moist room.

18. Repeat Steps IV.C. 1 – 17 for the other test specimens at the same cement content.
19. Repeat Steps IV. C. 1 – 18 for all other test specimens at the remaining cement contents.
20. Allow the specimens to remain in the moist room for 7 days.

D. Testing Specimens

1. Remove the specimens from the moist room.

Note C-8: *Protect specimens from moisture loss between removal from the moist room and breaking.*

2. Place the specimen on the lower bearing block of the testing machine, making certain that the vertical axis of the specimen is aligned with the center of thrust of the spherically seated upper bearing block. Raise the lower block until the specimen comes into contact with the upper block, aligning the upper block in order to obtain uniform seating (if applicable to the testing device).
3. Immediately apply load continuously, at the rate specified in Step II.N, without shock until the reading stabilizes or falls. Continue loading for approximately 10 – 15 seconds.
4. Record the failure load (load at which the reading stabilized or peaked) as Z, to the nearest graduation shown on the dial.
5. Remove the specimen from the machine. Grasp the top and bottom of the specimen and slowly twist in opposite directions. Record the type of break obtained as indicated on the worksheet.

Note C-9: *If the compression device requires a calibration chart to convert dial readings to failure load, record the dial reading and its corresponding failure load (Z) on the worksheet.*

6. Repeat Steps 2 – 5 for each specimen. Break all 4 sets of test specimens within 90 minutes from the time that the first cylinder is removed from the moist room.

E. Determination of Compressive Strength

1. Discard the highest and lowest failure loads (Z) (recorded in Step D.4) for each percent cement.
2. Determine the compressive strength of each of the three remaining test specimens at each percent cement in accordance with Step V.C., and record as P on the mix design worksheet.

Note C-10: *If the type of break recorded indicates an irregular failure pattern, the compressive strengths of these specimens should be analyzed to determine their suitability to be used in the average compressive strength for that set of specimens. Additional specimens may be necessary.*

3. Determine the average compressive strength for each percent cement in accordance with Step V.D. Record as Q on the mix design worksheet.

F. Determination of Curve Cement Factor

1. Label the vertical axis of the graph on the worksheet with a range of compressive strengths that includes the average compressive strengths of each set determined in Step E.3.
2. Plot the average compressive strength for each corresponding cement content
3. Draw a straight line connecting the points immediately above and below the design compressive strength line. (Refer to Introduction for design compressive strength.)
4. Select the point at which the design compressive strength line

intersects the line drawn in Step 3. This percent cement will be recorded to the nearest 0.1% on the Soil Cement Mix Design Worksheet as Curve Cement Factor.

G. Determination of Minimum Cement Factor
   1. To determine the minimum cement factor by mass, if the Curve Cement Factor is other than a whole percent, round it to the next whole percent and report as minimum Cement Factor by Mass on the mix design worksheet. If the Curve Cement Factor is a whole percent, report the Curve Cement Factor as Minimum Cement Factor by Mass.
   2. Determine the minimum cement factor by volume in accordance with Step V.E., using the Curve Cement Factor.

V. Calculations

A. Calculate the design moisture content (DM) to the nearest 0.1% using the following formula:

$$DM = DB + V$$

where:

DB = optimum moisture content for raw or lime treated material, %
V = constant (1.0% for A-4 and A-6 with 20% or more retained on the 4.75 mm (No.4) sieve and other soil groups containing only siliceous aggregate; 1.0% for all other materials 0.5% for other soils)

example:

DB = 12.1
V = 0.5

$$DM = 12.1 + 0.5$$
$$DM = 12.6$$

B. Calculate the slake water (M), the quantity of water needed to bring each test specimen to the slaked moisture content, to the nearest mL using the following formula:

Note C-11: *1 g water = 1 mL water*

$$M = K \times \left(\frac{DM - 5}{100}\right)$$

where:

K = mass of test specimen, g
DM = design moisture content, %
5 = constant, represents % moisture
100 = constant, converts whole number percent to decimal

example:

K = 6678
DM = 12.6

$$M = 6678 \times \left(\frac{12.6 - 5}{100}\right)$$
$$= 6678 \times \left(\frac{7.6}{100}\right)$$
$$= 6678 \times (0.076)$$
$$= 507.52$$
$$M = 508$$

C. Calculate the compressive strength (P) of each test specimen to the nearest 10 kPa (psi) using the following formula:

METRIC:

$$P = \frac{Z}{0.01826}$$

where:

Z = failure load, kN
0.01826 = constant, cross sectional area of specimen, m^2

example:

Z = 28.34

$$P = \frac{28.34}{0.01826}$$

$$P = 1552$$
$$P = 1550$$

ENGLISH:

$$P = \frac{Z}{28.3}$$

where:

Z = failure load, lb
28.3 = constant, cross sectional area of specimen, $in.^2$

example:

Z = 6370

$$P = \frac{6370}{28.3}$$

$$P = 225.08$$
$$P = 225$$

D. Calculate the average compressive strength (Q) to the nearest 10 kPa (psi) using the following formula:

$$Q = \frac{P_1 + P_2 + P_3}{3}$$

where:

P_1, P_2, P_3 = comp. str. of the 3 individual test spec.
3 = constant, number of specimens

example:

METRIC:

P_1 = 1550
P_2 = 1630
P_3 = 1590

$$Q = \frac{1550 + 1630 + 1590}{3}$$

$$= \frac{4770}{3}$$
$$= 1590$$

ENGLISH:

P_1 = 225
P_2 = 252
P_3 = 270

$$Q = \frac{225 + 252 + 270}{3}$$

$$= \frac{752}{3}$$
$$= 249.00$$
$$Q = 249$$

E. Calculate the minimum cement factor by volume by using the Additive Conversion Chart. This chart may be used for Type I, IB, or II portland cement.

4. Enter the chart on the left scale. Reading vertically, place a point at the appropriate maximum dry mass density (DC) of the raw soil on the mix design worksheet.
2. Reenter the chart on the cement (center) scale. Reading vertically, place a point at the Curve Cement Factor percent.
3. Draw a straight line across the chart connecting the two points plotted in Steps 1 and 2, extending the line to intersect with the Additive Percent By Volume (right) scale.
4. Read the percent by volume directly from the right scale where the line intersects the right scale.
5. Round any partial percent to the next higher whole percent. Record this value as minimum cement factor by volume on the mix design worksheet.
6. Example: *Type IB Cement, Figure C-1*

   A = 2050 kg/m³ (128 lb/ft³)
   Curve Cement Factor = 7.0%

   (1) Follow the left scale to the point represented by 2050 kg/m³ (128 lb/ft³)
   (2) Follow the center scale to the point represented by 7.0% by mass
   (3) Draw a straight line across the scale, connecting the two points and extending it to intersect the right scale.
   (4) The percent cement by volume, read directly from the right scale, is 8.9%.
   (5) Round 8.9% to 9.0% and record.

7. In lieu of the charts or if values are not covered by the charts, calculate the percent by mass of cement (V) to the nearest percent using the following formula:

$$V = \frac{DC}{[(\frac{1}{R}) + 0.01] \times U}$$

where:

DC = max. dry wt. density of the soil agg., kg/m³ (lb/ft³)
U = unit wt of additive, kg/m³ (lb/ft³)
R = Curve Cement Factor, %
0.01 = constant
1 = constant

example: *Type IP Cement*

METRIC:

DC = 2050 kg/m³
R = 6.2%
U = 1440 kg/m³

$$V = \frac{2050}{[(\frac{1}{6.2}) + 0.01] \times 1440}$$

$$= \frac{2050}{(0.16 + 0.01) \times 1440}$$

$$= \frac{2050}{0.17 \times 1440}$$

$$= \frac{2050}{244.8}$$

$$= 8.37$$

$$V = 9$$

ENGLISH:

DC = 128 lb/ft³
R = 6.2%
U = 90 lb/ft³

$$V = \frac{128}{[(\frac{1}{6.2}) + 0.01] \times 90}$$

$$= \frac{128}{(0.16 + 0.01) \times 90}$$

$$= \frac{128}{0.17 \times 90}$$

$$= \frac{128}{15.30}$$

$$= 8.36$$

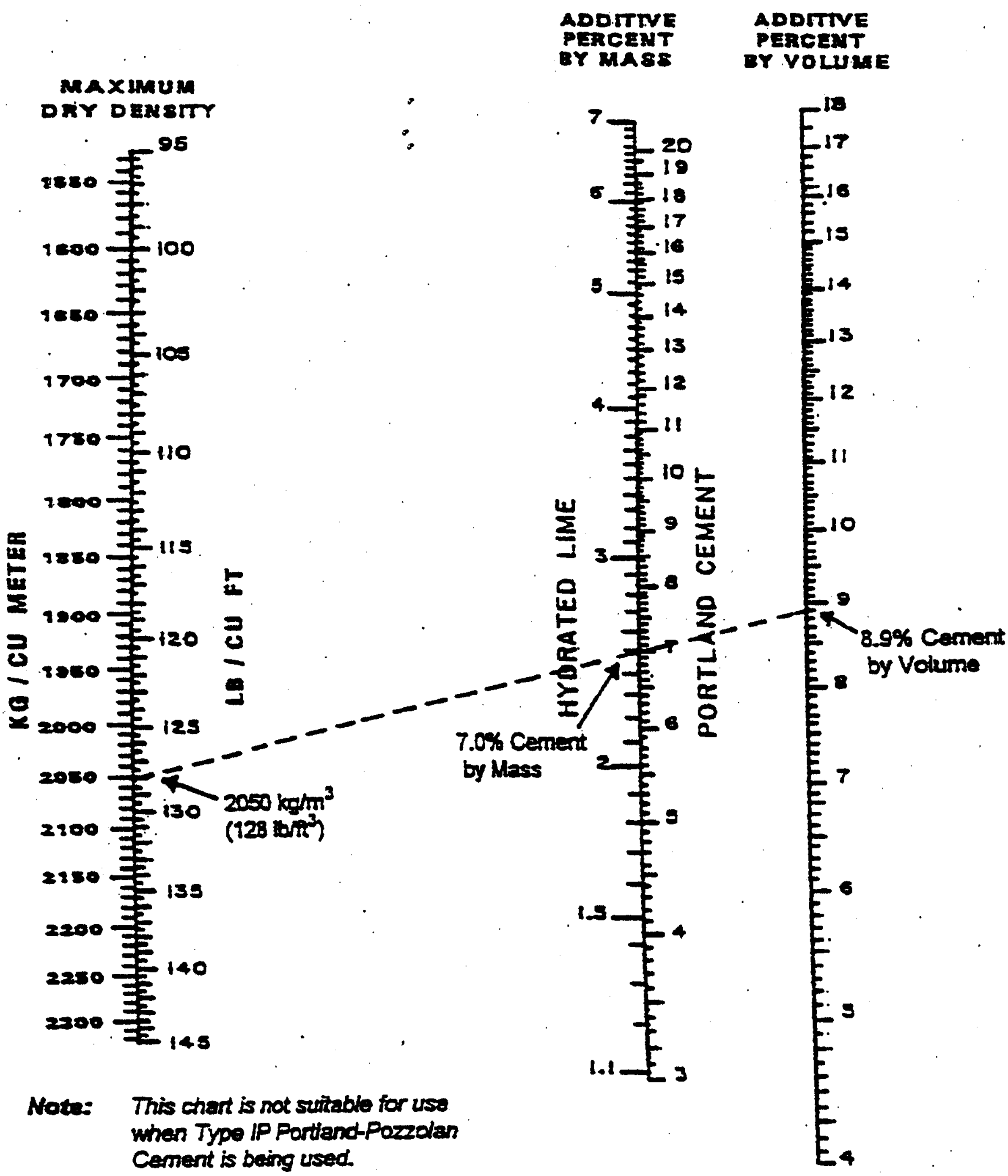
$$V = 9$$

VI. Report

Report the minimum cement factor by volume or by mass as applicable to the specification item.

VII. Normal Test Reporting Time

Normal test reporting time is a maximum of 21 days, including the completion of all prerequisite testing.



Note: *This chart is not suitable for use when Type IP Portland-Pozzolan Cement is being used.*

ADDITIVE CONVERSION CHART

RELATION IN PERCENT BY MASS OF OVEN-DRY SOIL, SOIL-AGGREGATE, OR AGGREGATE TO DESIGN PERCENT BY VOLUME

Additive Conversion Chart
Figure C-1

DOTD 03-22-0757
Metric/English
Rev. 4/99

SOIL-CEMENT MIX DESIGN WORKSHEET
DOTD TR 432 METHODS B & C

PROJECT NO.: 450-11-0002 COMPOSITE NO(S).: ______ SAMPLE NO.: SC LAB NO.: 22-456790

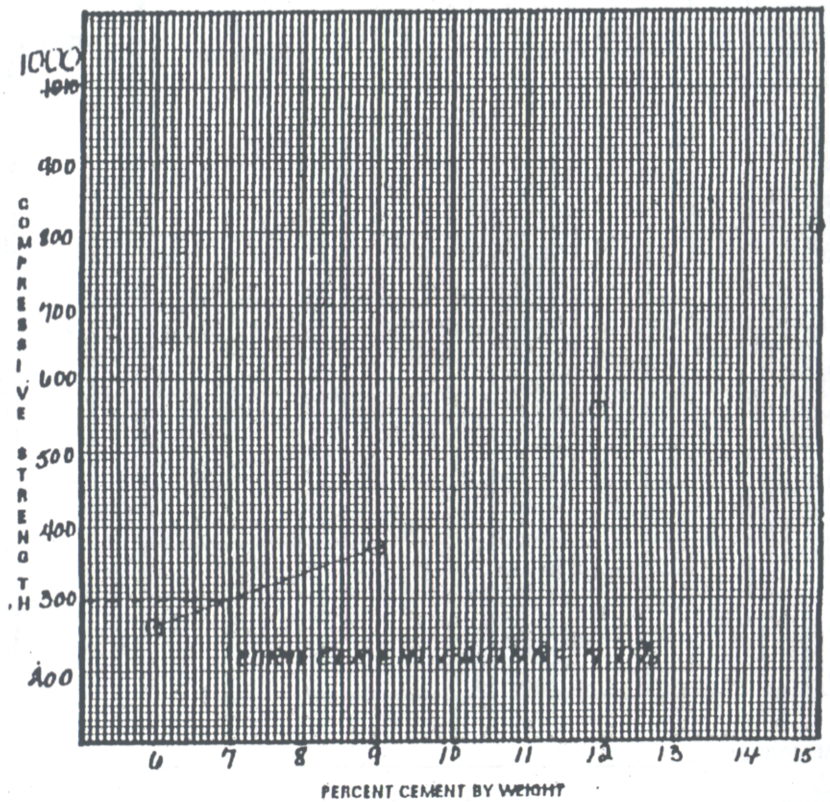
TYPE SOIL: Grav Sdy Lm DATE MOLDED: 3/17/99 TESTED BY: ______ CHECKED BY: L.C.

BREAK DATE: 3/23/99 MIN. CEM. FACTOR: 7 % By Mass (Wt) 9 % By Vol. OPT. MOIST., % ______ MAX. DWD ______

(Cement Stabilized or Treated Material)

COMPRESSION TEST DATA

Cylinder Number	% Cem't by Wt.	Break Code	Dial Reading	Failure Load (Z) (kN or Lb)	Compressive Strength (F) (MPa or PSI)	Average Compressive Strength (Q) (MPa or PSI)
E-1		2		7845		
E-2		1		6962	246	
E-3	6	1		7130	252	256
E-4		1		7640	270	
E-5		1		5830		
F-1		1		11320	400	
F-2		1		9360		
E-3	9	1		10755	380	385
F-4		1		10610	375	
F-5		1		11415		
G-1		2		12120		
G-2		1		15960	564	
G-3	12	1		16160	571	560
G-4		1		14305		
G-5		1		15425	545	
H-1		1		23405	827	
H-2		1		22640	800	
H-3	15	1		20165		809
H-4		1		22640	800	
H-5				23930		



REMARKS: ______

TYPE OF BREAK 1 = Regular 2 = Irregular

DESCRIPTION

Soil Cement Mix Design Worksheet, DOTD 03-22-0757
Figure C-2 (Front) *English*

SOIL-CEMENT MIX DESIGN WORKSHEET

DOTD TR 432 METHODS B & C

DOTD 03-22-0757
Metric/English
Rev. 4/99

PROJECT NO.: 450-11-0002 COMPOSITE NO(S).: ______ SAMPLE NO.: SC-2 LAB NO.: 22-456790

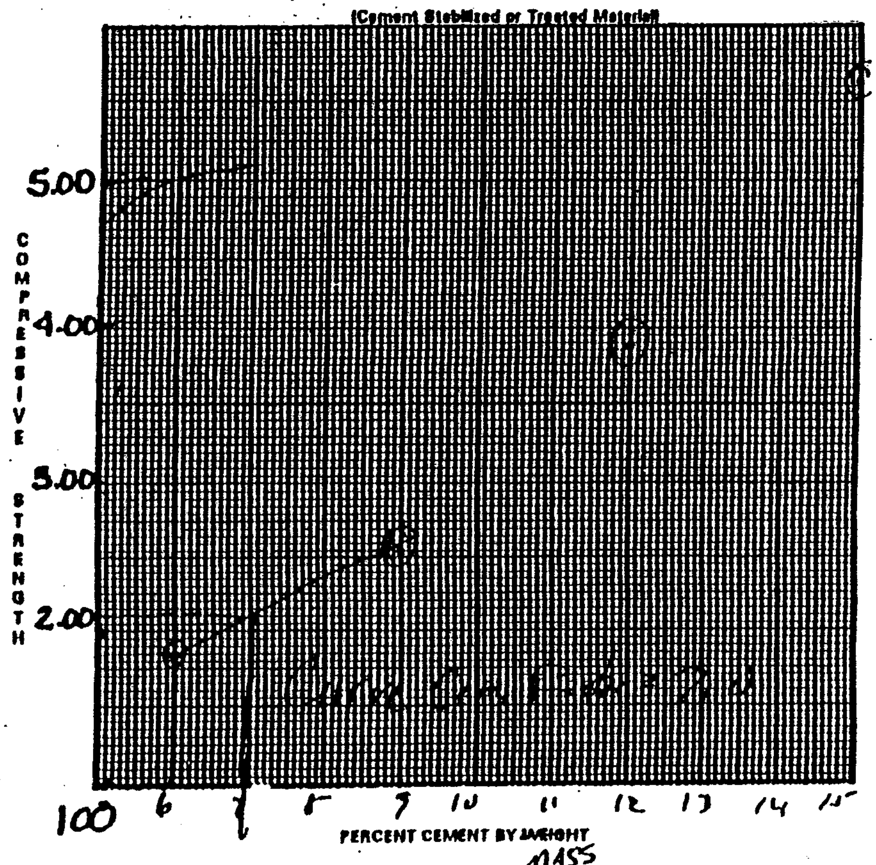
TYPE SOIL: Grav. Sdy Lm DATE MOLDED: 4/17/99 TESTED BY: D.B. CHECKED BY: L.C.

BREAK DATE: 4/23/99 MIN. CEM. FACTOR: 7 % By Mass (Wt) 9 % By Vol. OPT. MOIST., % ______ MAX. DWD ______

COMPRESSION TEST DATA

Cylinder Number	% Cem't by Mass (Wt)	Break Code	Dial Reading	Failure Load (Z) (kN or Lb)	Compressive Strength (P) (MPa or PSI)	Average Compressive Strength (Q) (MPa or PSI)
E-1	6			34.89		1.76
E-2				36.97	1.69	
E-3				31.72	1.73	
E-4				38.98	1.86	
E-5				25.93		
F-1	9			60.35	2.75	2.65
F-2				41.19		
F-3				47.84	2.62	
F-4				47.19	2.58	
F-5				60.77		
G-1	12			63.91		3.70
G-2				70.99	3.88	
G-3				71.88		
G-4				63.67	3.48	
G-5				68.61	3.75	
H-1	15			104.11	5.70	5.57
H-2				100.70	5.50	
H-3				89.19		
H-4				100.70	5.59	
H-5				106.44		

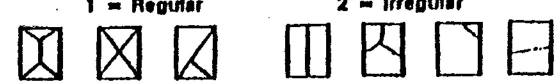
(Cement Stabilized or Treated Material)



REMARKS: ______

TYPE OF BREAK 1 = Regular 2 = Irregular

DESCRIPTION



Soil Cement Mix Design Worksheet, DOTD 03-22-0757
Figure C-2 (Front) *Metric*

SOIL CEMENT DESIGN CALCULATIONS
DOTD TR 432 - METHODS B & C

OPTIMUM MOISTURE AND DESIGN MOISTURE

Soil Group (TR 423) A-2-6 (0) Classification (TR 423) Grav. Sdy. Lm.

Optimum Moisture Content of Material (DB) = 12.1 % Design Moisture Content (DM = DB + V) = 12.6 %

Max. Dry Density of Material (DC) = 2050

(DOTD TR 415 ____ DOTD TR 418 ____)

For A-4 and A-6 Soils, V = 1.0%
For all other soils, V = 0.5%

METHOD B

% Cement (by wt.)	Dry Weight of Material (g)	Cement (g)	Material + Cement (g)	Evap (mL)	Slake Water (mL)	Slake Time	Net Water (mL)	Net Water Time	Molding Time
H	I	J	K	L	M		N		
					K x (DM -5)/100		L + 0.05K		
6	2300	138	2438	24			146		
9		207	2507	25			150		
12		276	2576	26			155		
15		345	2645	26			158		

METHOD C

% Cement (by wt.)	Dry Weight of Material (g)	Cement (g)	Material + Cement (g)	Evap (mL)	Slake Water (mL)	Slake Time	Net Water (mL)	Net Water Time	Molding Time
H	I	J	K	L	M		N		
					K x (DM -5)/100		L + 0.05K		
6	6300	378	6678	67	508	7:45	401	8:15	9:15
9		567	6867	69	522	8:05	412	8:35	9:35
12		756	7056	71	536	8:25	434	8:55	9:55
15		945	7245	72	550	8:50	434	9:15	10:15

Soil Cement Mix Design Worksheet, DOTD 03-22-0757
Figure C-2 (Back)

DOTD Designation: TR 432-02

Method D – Durability of Cement Treated or Stabilized Materials

I. Scope

This method is designed to determine the durability of cement treated or stabilized materials which have met minimum design strength when tested in accordance with Method B or C, or of materials for which a minimum cement content has been determined in accordance with Method A.

II. Apparatus

Apparatus listed in AASHTO T 135.

III. Sample

Two specimens molded in accordance with Step IV of Method B or C, as applicable.

IV. Procedure

Test specimens in accordance with AASHTO T 135, beginning with the Section title Molding Specimens, Paragraph 7.2 and continuing through Calculations, Paragraph 9.1.4.

V. Report

A. Report the percent loss by mass.
B. Compare the percent loss by mass to Table 2 to determine the acceptability of the material at the minimum cement factor determined in Method A, B, or C.

VI. Normal Test Reporting Time

Normal test reporting time is 4 weeks.

Soil Group	Maximum Loss, % by Dry Mass
A-1-A, A-1-B, A-2-4,	14
sandshell, sand clay gravel, recycled material, etc.	14
A-2-6, A-4	10
A-6	7

TABLE 2